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Kirk et al.

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(54) **GAS FLOTATION TANK**

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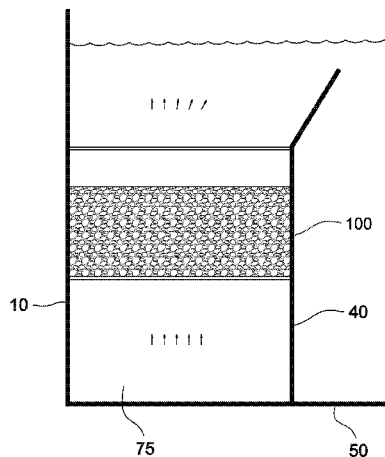
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(57) **ABSTRACT**

A gas flotation tank is provided that includes a series of
adjacent chambers which impart a rotational current therein.
Each chamber is separated from a skim oil trough by a
skimming weir. Each chamber comprises an alternating fluid
communication device between adjacent chambers allowing
fluid communication between adjacent chambers in the form
of a communication port in the dividing wall between
adjacent chambers and a chamber outlet in conjunction with
a perforated plate and the outlet is positioned in fluid
communication with the final chamber. An optional coalesc-
ing media may be positioned in or proximate the commu-
nication port to absorb or coalesce contaminants as they pass
therethrough.

18 Claims, 11 Drawing Sheets



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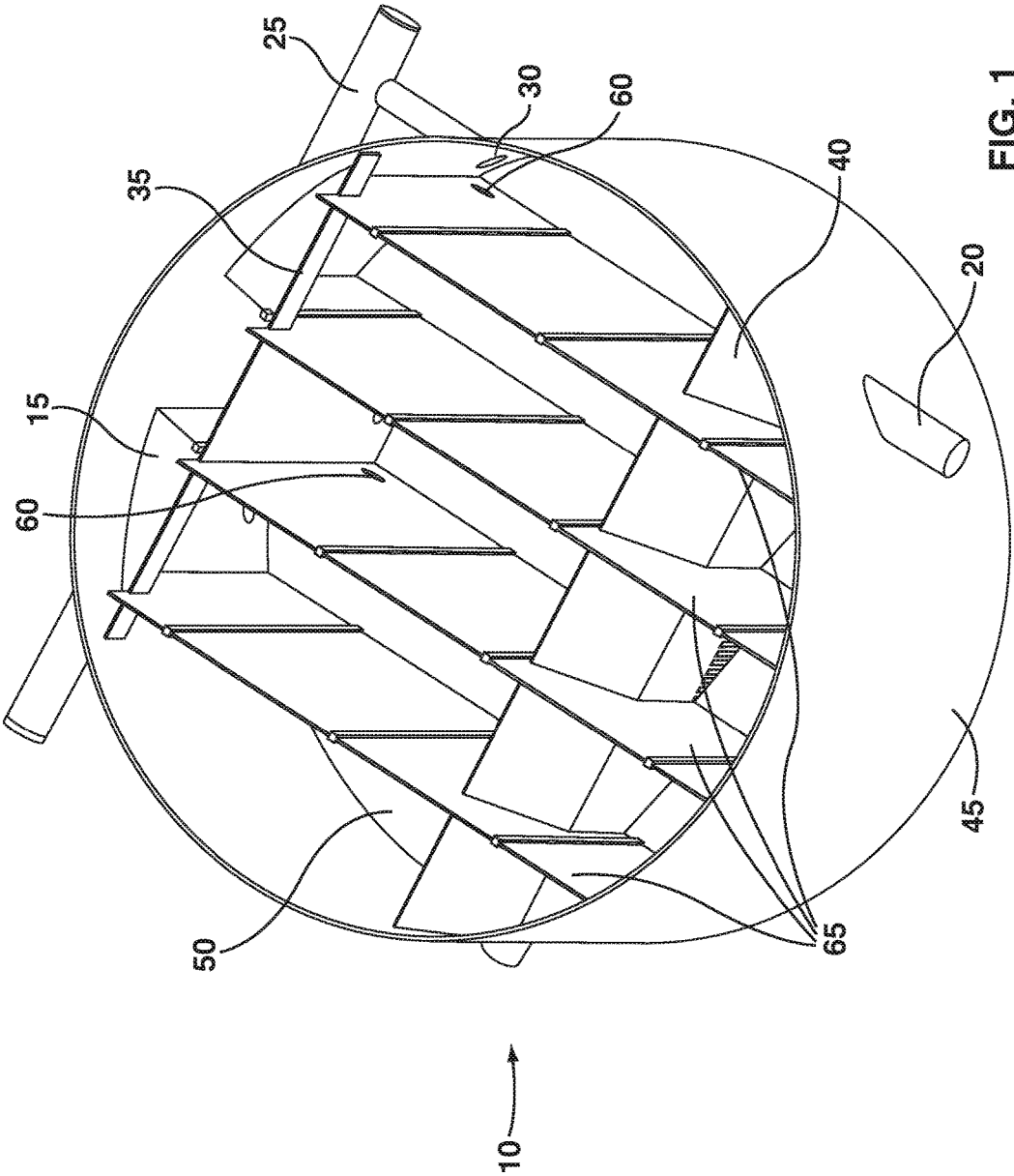


FIG. 1

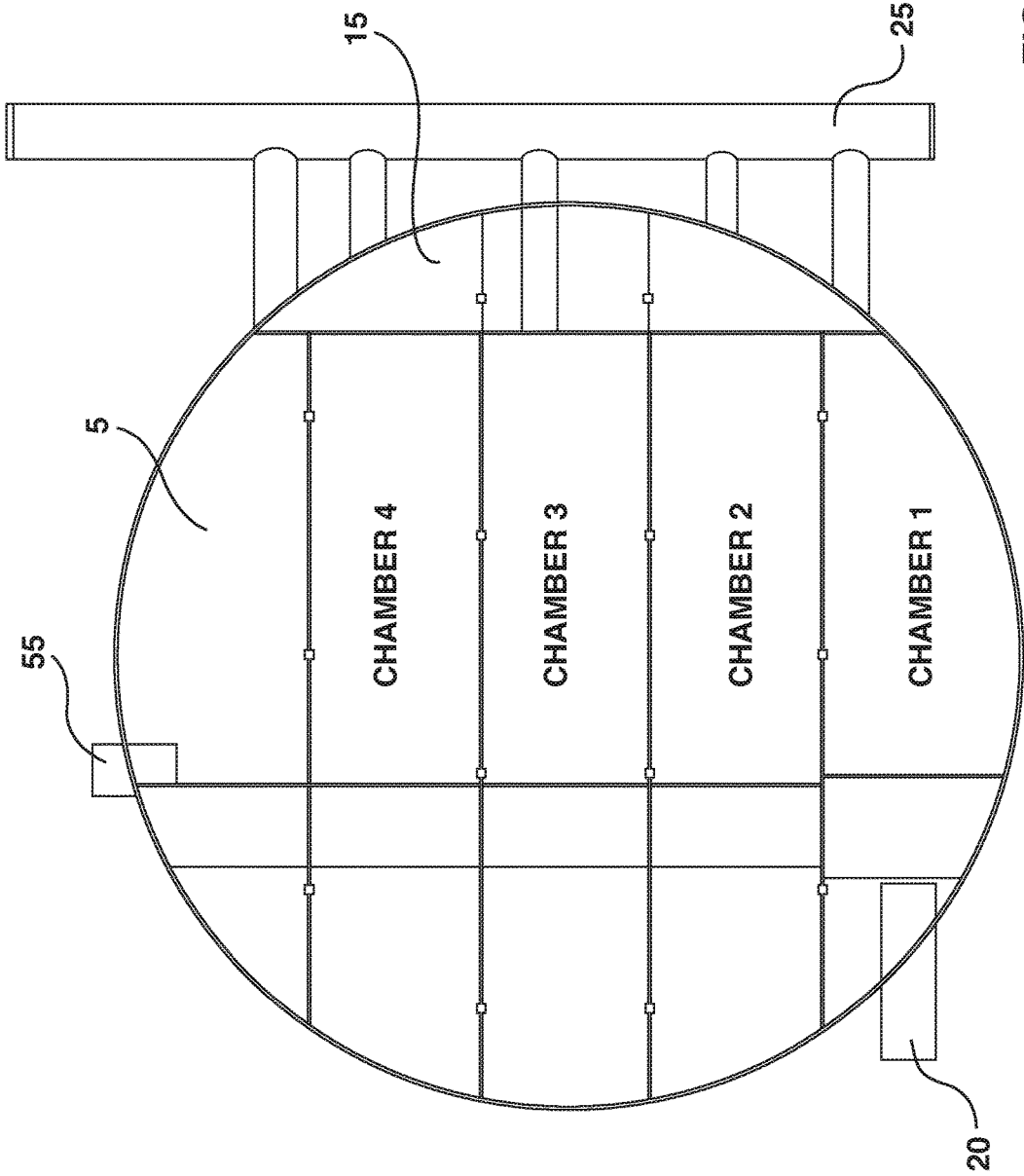


FIG. 2

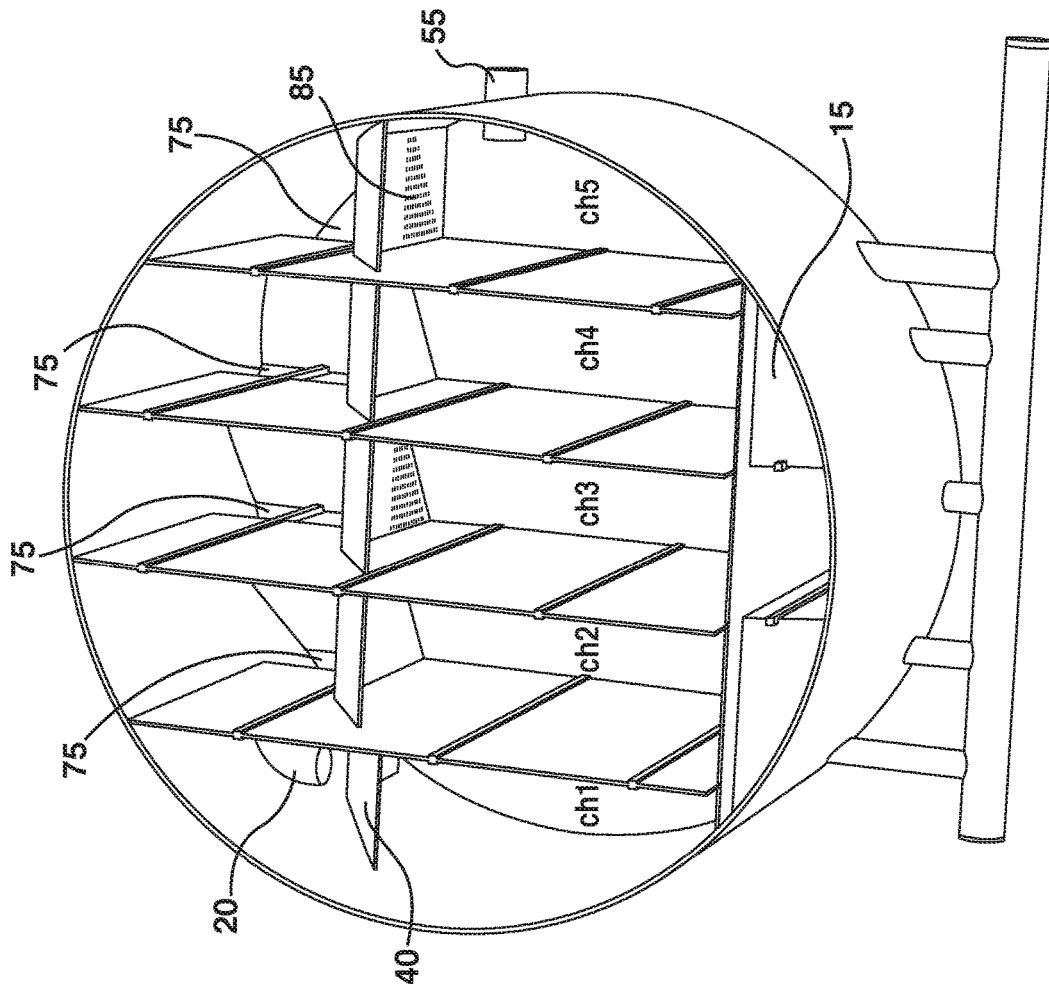


FIG. 3

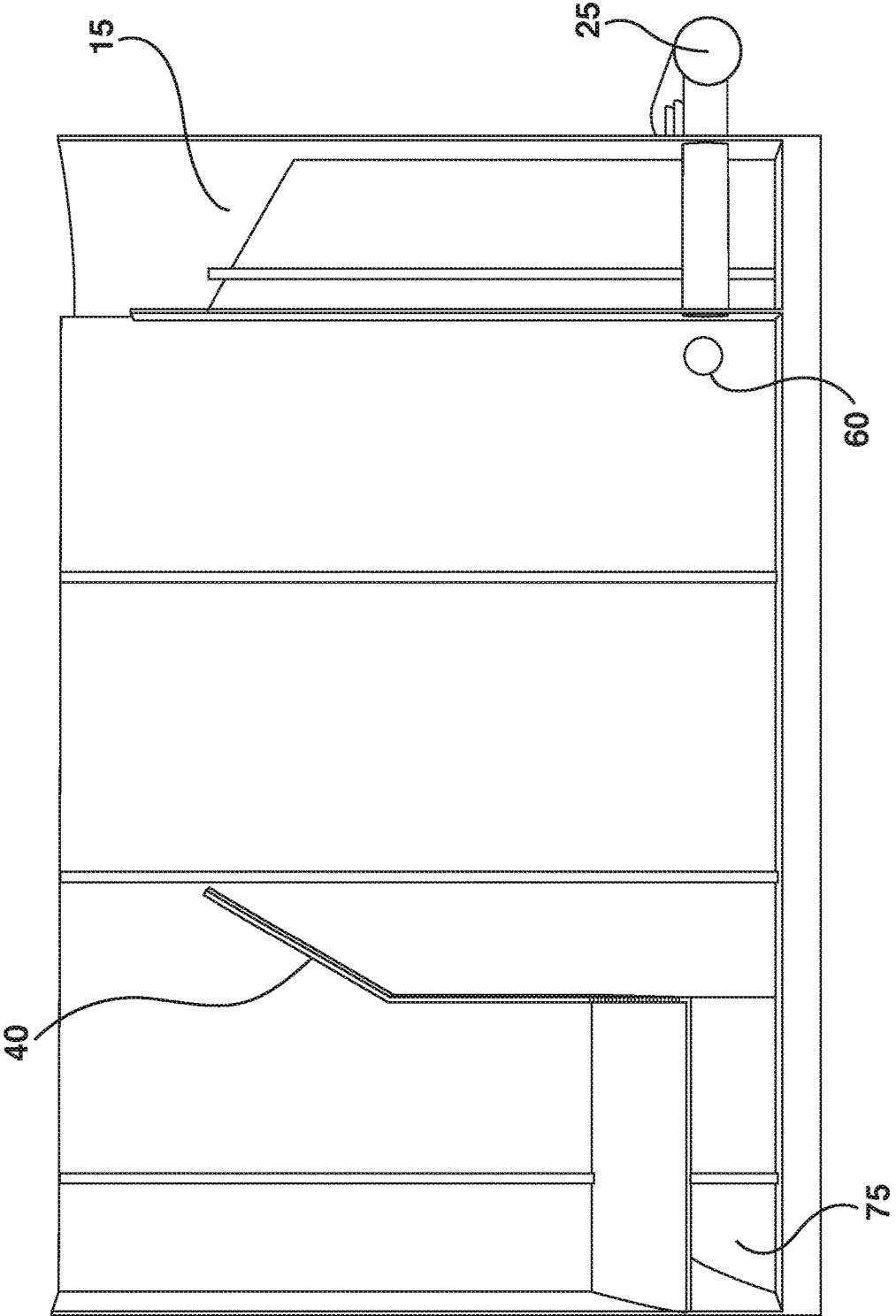


FIG. 4

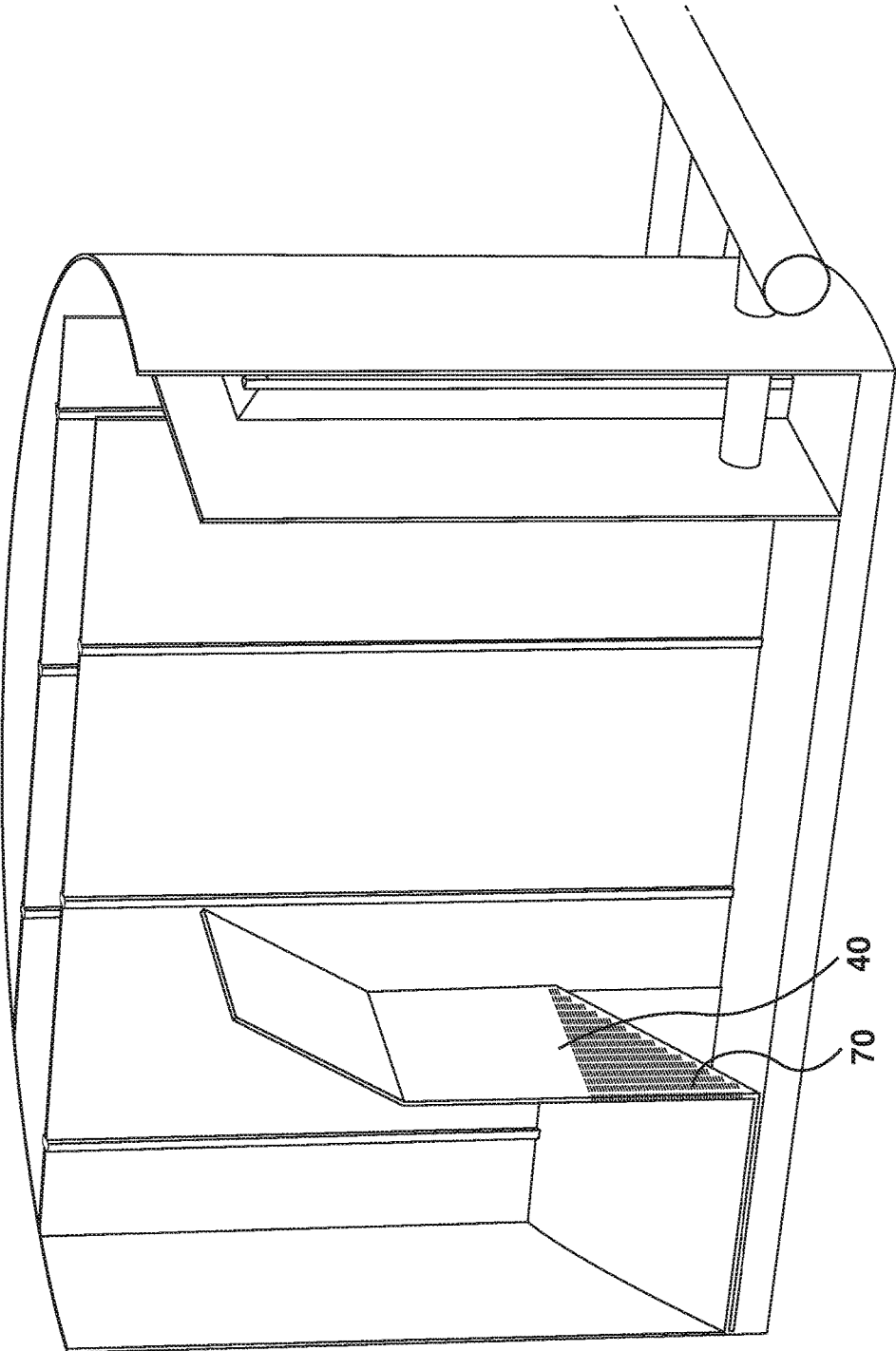


FIG. 5

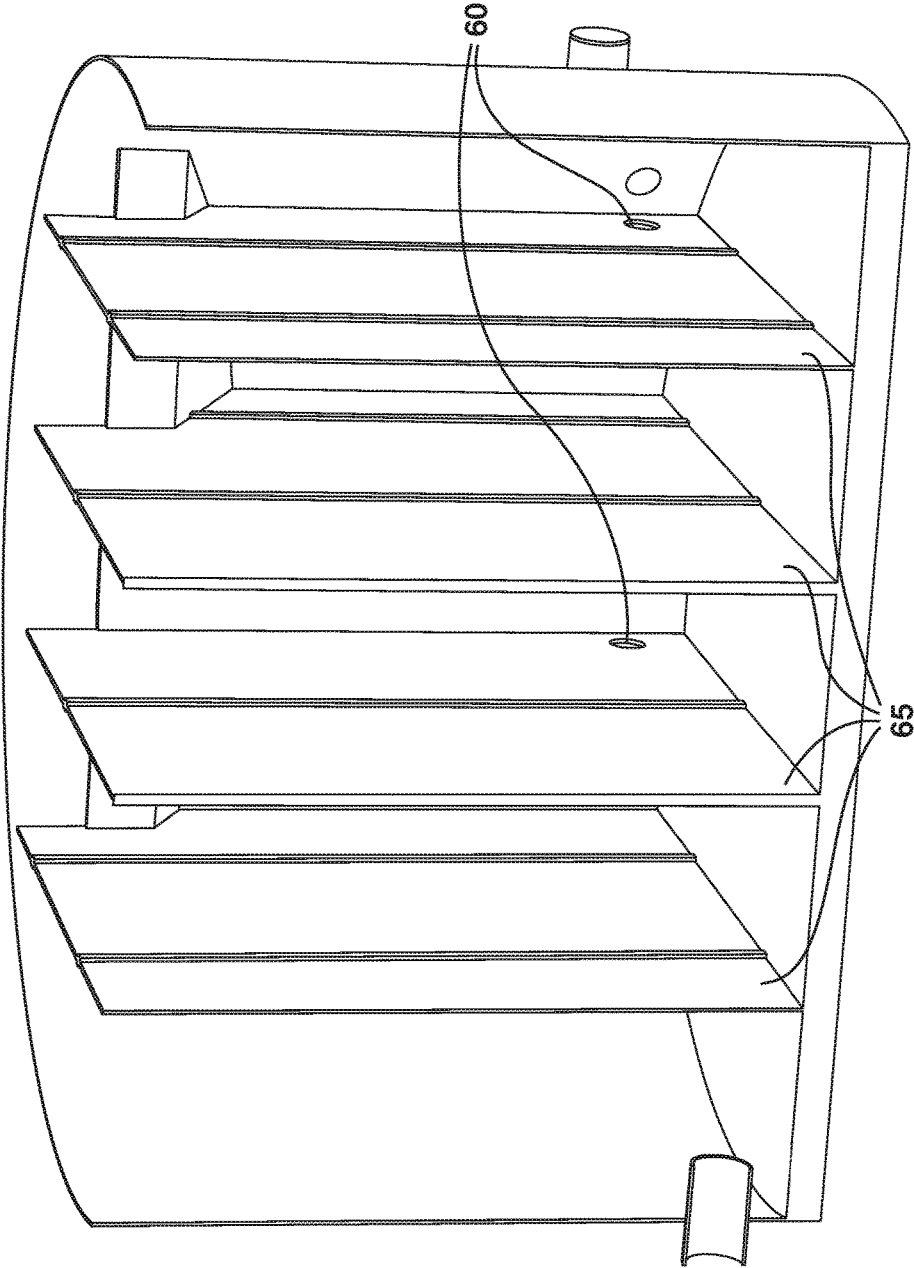


FIG. 6

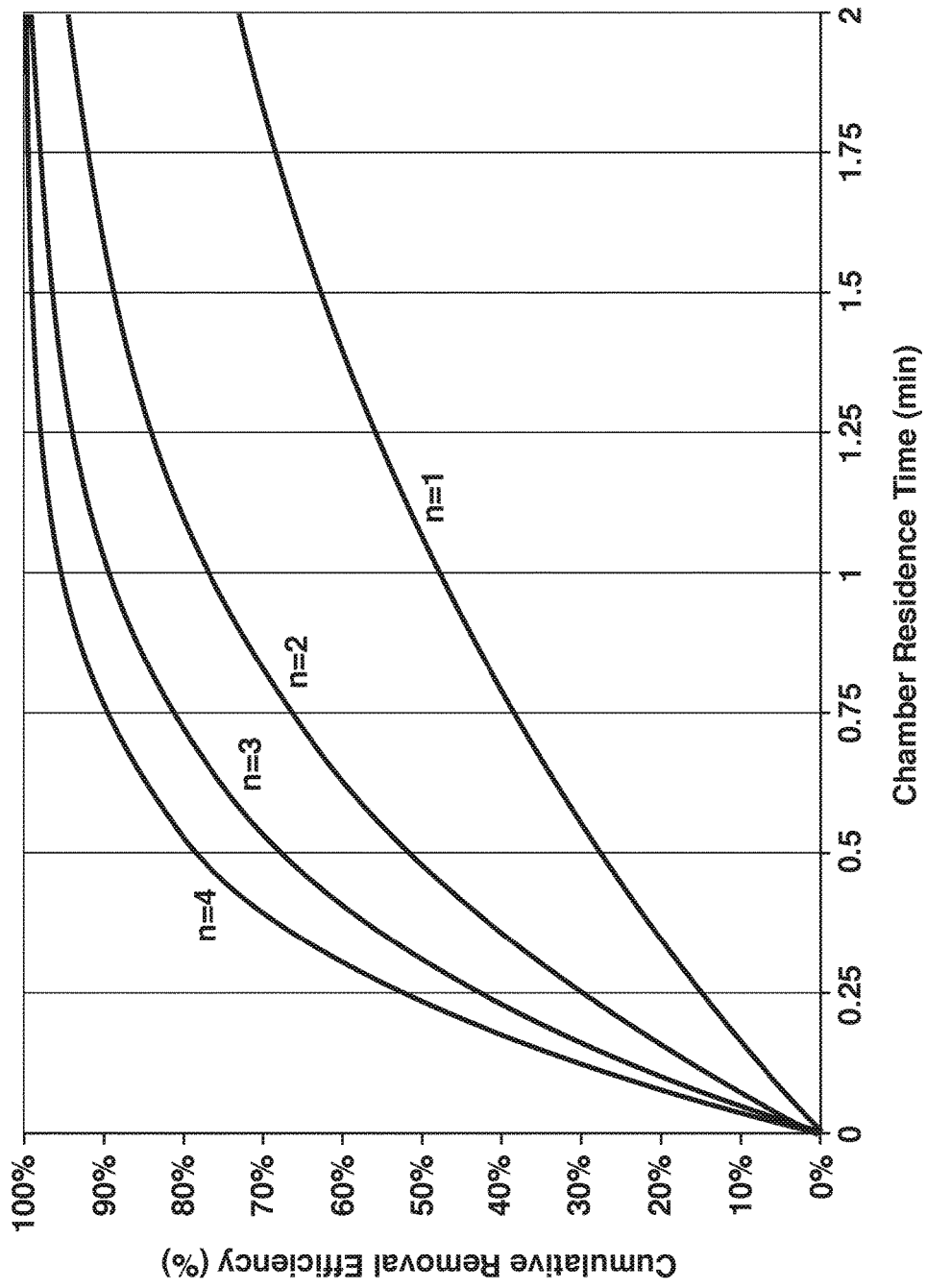


FIG. 7

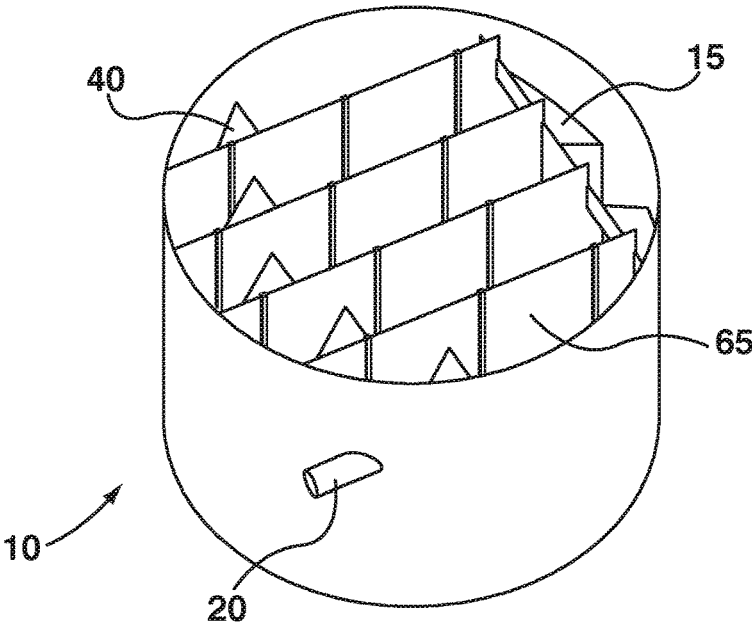


FIG. 8

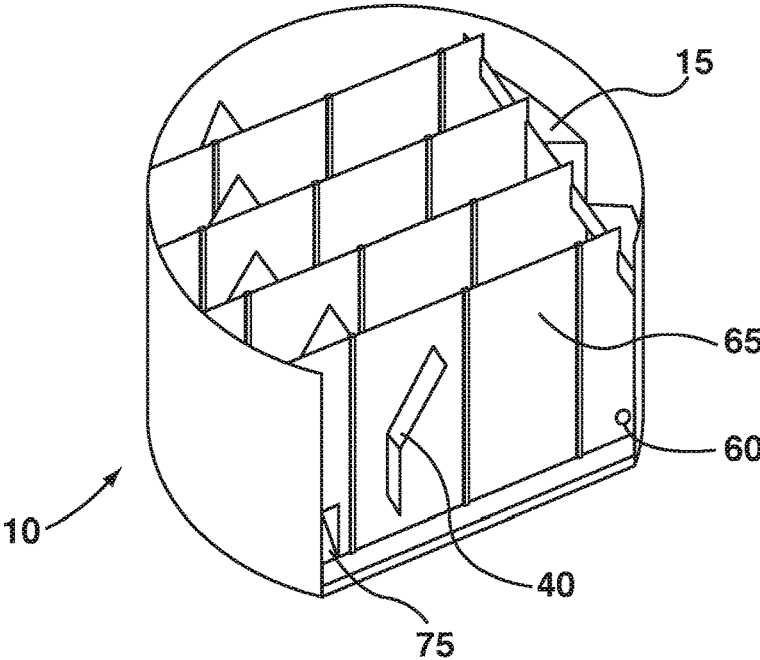


FIG. 9

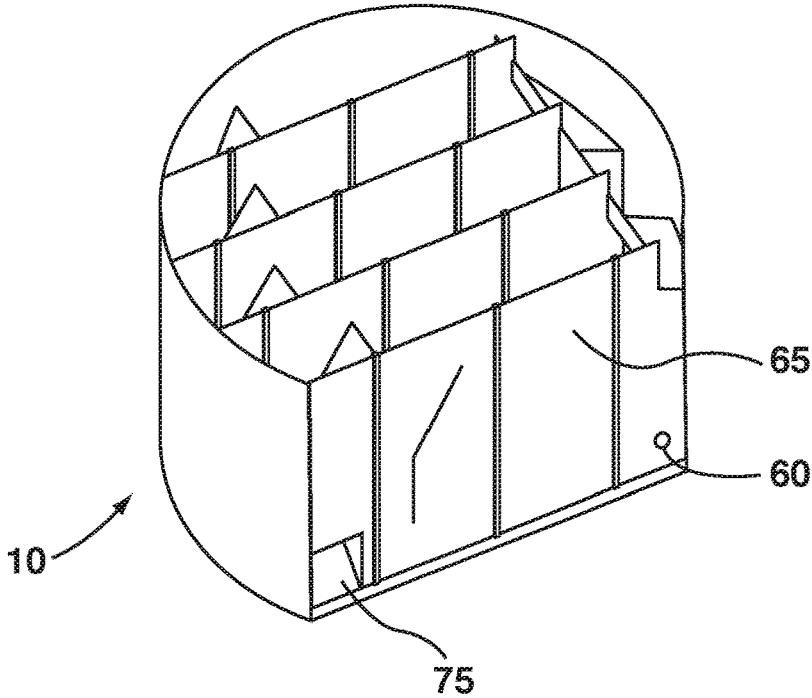


FIG. 10

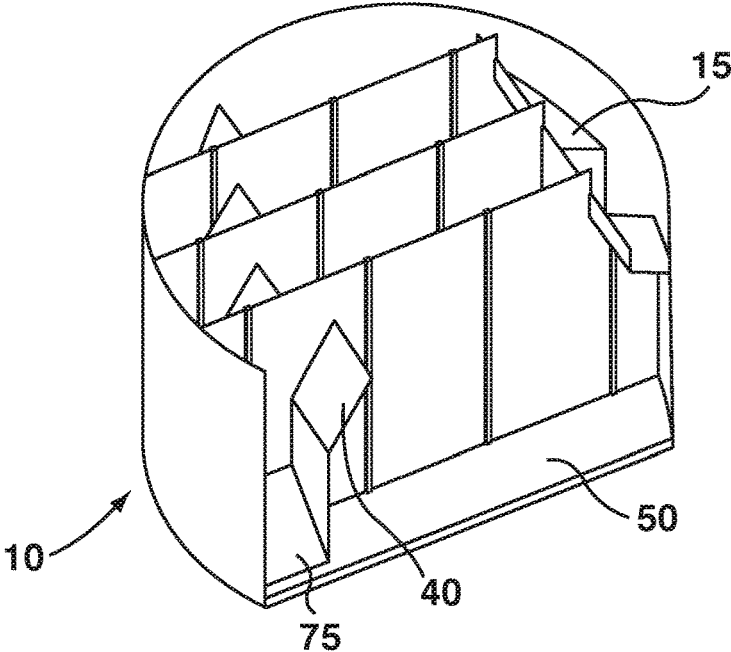


FIG. 11

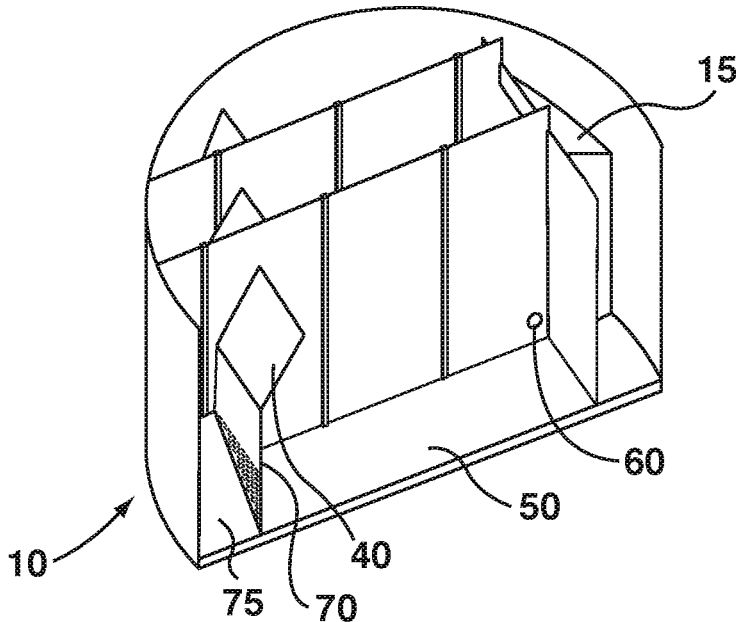


FIG. 12

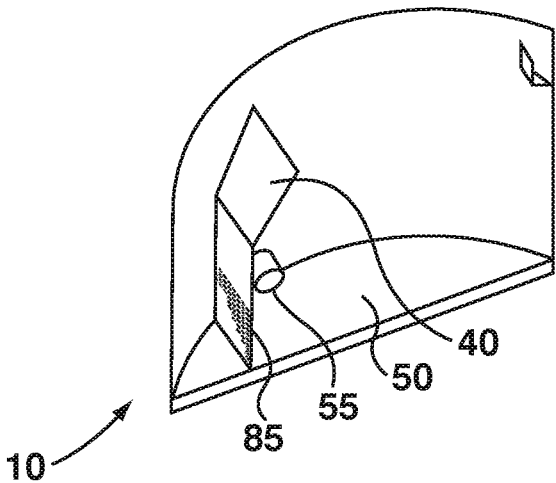


FIG. 13

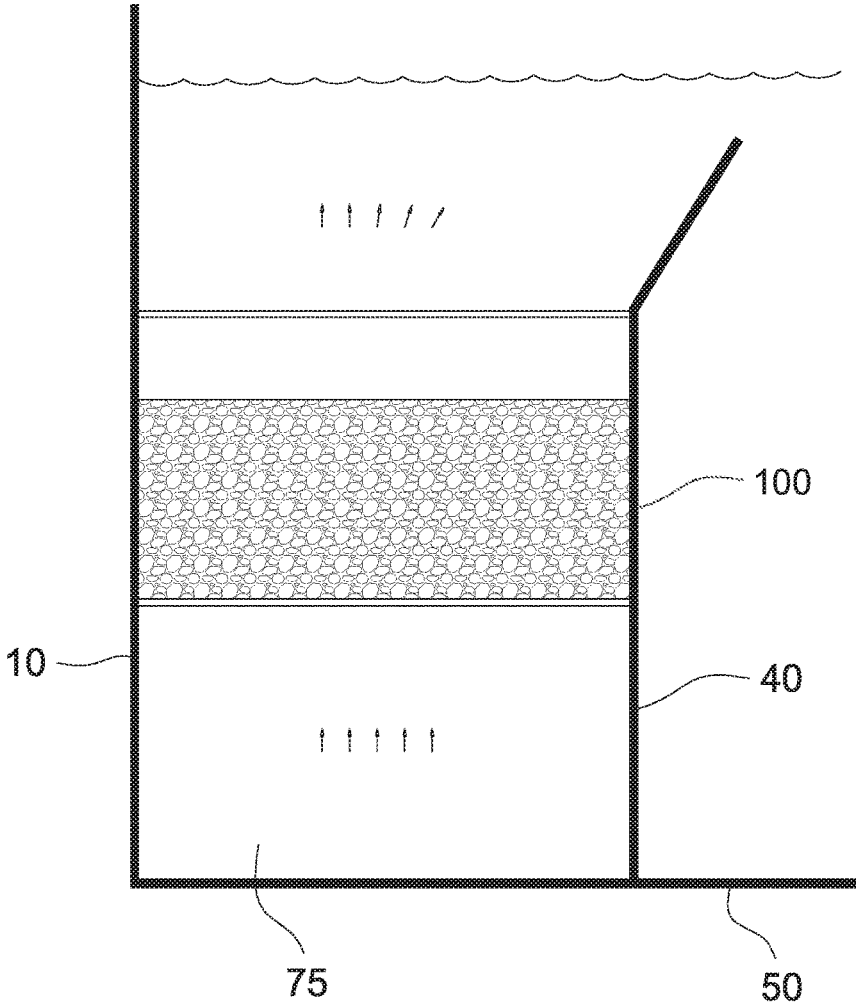


FIG. 14

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GAS FLOTATION TANK

RELATED APPLICATIONS

This application is a continuation-in-part application of U.S. patent application Ser. No. 14/914,610 filed Feb. 25, 2016, which is the U.S. National Phase of PCT/CA/2014/050751 filed Aug. 8, 2014, which in turn claims priority to U.S. Ser. No. 13/975,750 filed Aug. 26, 2013. The subject matter of each of these applications is incorporated herein by reference in entirety.

FIELD OF THE INVENTION

The invention relates to gas flotation tanks for separating hydrocarbons from produced water and more specifically to gas flotation tanks with reduced structural and internal piping that prevent, reduce or at least mitigate short circuiting.

BACKGROUND

Gas flotation tanks are used to separate unwanted phases or contaminants such as hydrocarbons from produced water generally by allowing or facilitating the rising of the unwanted phases or contaminants to the surface of produced water. The hydrocarbons may then be removed via skimming of the surface of the produced water.

One typical gas flotation tank comprises of a number of chambers separated by a dividing wall but in fluid communication with each other. During operation, produced water is input into the tank and a rotational current is generated promoting hydrocarbon to rise to the surface of the water in the tank while forcing cleaner more purified water towards the bottom of the tank. By passing the lower water to an adjacent chamber via a fluid communication port, each successive chamber contains produced water having a lower content of hydrocarbons until a desired purity level is reached and the water is output from the gas flotation tank. One problem with such a design is the need for heavily reinforced divider walls between each chamber of the gas flotation tank as fluid levels in each chamber can be unequal and the difference in fluid level can be significant enough to damage the divider wall and the tank. In addition, depending on the location of the fluid communication port between each divider wall of the tank, water can short circuit across the chambers resulting in water in the final chamber being output with a higher than desirable hydrocarbon content.

To avoid short circuiting, one gas flotation tank includes an interconnecting pipe to connect the chambers in series without creating a short circuit from the inlet to the outlet. The interconnecting pipe is located in such a way that the water considered to be cleanest is taken from one chamber to the next, released near the surface, and dispersed in a fashion (in conjunction with a water weir) to create a flow pattern and velocities that facilitate skimming of the surface hydrocarbon towards an oil skimming trough. The interconnecting pipe also acts as a region in which "micro-bubbles" may be introduced before entering subsequent chambers to ensure even mixing with flow going into each chamber.

However, the interconnecting pipe allows for, in an upset condition, an uncontrolled increase or decrease inlet flow, resulting in a large level difference between chambers that can collapse the internal walls hence requiring a need to heavily reinforce the tank. In order to minimize the risk of large level differences the interconnecting pipe size can be increased. However, such an increase can obstruct the flow

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pattern within the tank as well as reduce the working volume of the chamber thus rendering the tank less efficient. In addition, such an interconnecting pipe is limited by standard pipe and rolled plate sizes and associated costs. Furthermore, filling and draining the tank is a delicate process that requires careful monitoring of the level in each chamber.

Another type of flotation tank is referred to as a serpentine tank and includes a number of chambers, each chamber separated by a partition wherein a portion of the partition is a perforated plate or opening, allowing for the balancing of the chambers. However, a serpentine tank allows only for horizontal flow through the tank, wherein gravity and time are used for the separation of the unwanted phases. The fluid in a serpentine tank flows substantially in one direction inside the chamber (lengthwise) and exits the chamber through the perforated plate, or open section, to the adjacent chamber where it flows horizontally the length of that chamber, repeating for as many chambers as is provided in a given tank, hence the term "serpentine". This pattern of going end to end also creates the requirement for individual skimming points in each chamber, which also requires additional nozzles on the tank, external piping, and valves for removing the unwanted phases.

A need therefore exists for a gas flotation tank that prevents, reduces or mitigates short circuiting while reducing or removing the dependency on interconnecting piping.

SUMMARY

A gas flotation tank for separating contaminants from fluid is provided. The tank includes a series of adjacent chambers which impart a rotational current therein through the use of a sloped weir in each chamber. Each chamber is separated from a skim oil trough by a skimming weir over which the contaminants pass. Each adjacent chamber is fluidly connected via an interconnecting passage that allows for the transfer of reduced contaminant fluid to an adjacent chamber for further contaminant reduction. An alternating setup of fluid passages and connector ports between adjacent chambers allows for at least partial equalization of the fluid level between adjacent chambers and further mitigates, reduces or prevents short circuiting of the fluid as it passes from chamber to chamber. An optional coalescing media may be positioned in or proximate one or more of the interconnecting passages to absorb or coalesce contaminants as they pass therethrough.

In one embodiment, there is provided a flotation tank for removing a contaminant from fluid input into the flotation tank, the flotation tank comprising;

a floor defining a bottom of the tank and a depending wall defining the sides of the tank;

a series of adjacent chambers within the tank separated from each other by dividing walls, each chamber comprising a sloped weir for inducing a rotational current within the chamber;

a skim oil trough spanning each chamber and separated from each chamber by a skimming weir, the skimming weir opposite the sloped weir;

an inlet in fluid communication with a chamber of the series of adjacent chambers for inputting a fluid comprising a contaminant, the inlet situated proximate the sloped weir of the series of adjacent chambers for inducing a rotational current to fluid input into the chamber;

each chamber in fluid communication with the adjacent chambers via an interconnecting passage positioned substantially towards the bottom of the dividing wall of

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each chamber and substantially opposite the skim oil trough, the interconnecting passage allowing passage of fluid from a chamber to a backside of the sloped weir of the adjacent chamber;

a connector port in the dividing wall between two adjacent chambers for providing fluid communication between the two adjacent chambers;

a fluid passage in the sloped weir of at least one of the chambers of the series of adjacent chambers allowing for fluid transfer between adjacent chambers through the sloped weir of the at least one chamber; and

an outlet in fluid communication with one of the chambers of the series of adjacent chambers outputting produced water;

a coalescing media positioned in or proximate one or more of the interconnecting passages for absorbing or coalescing contaminants as they pass through the interconnecting passage;

wherein the connector port and the fluid passage are situated in alternating adjacent chambers.

In a further embodiment of a flotation tank to that described above, the connector port is positioned in the base of the dividing wall proximate the skimming weir.

In a further embodiment of a flotation tank to that described above, the interconnecting passage is positioned at one end proximate the base of the sloped weir and at the other end in proximity to a backside of the sloped weir of the adjacent chamber.

In a further embodiment of a flotation tank to that described above, the fluid passage is positioned proximate the base of the sloped weir.

In a further embodiment of a flotation tank to that described above, the fluid passage is a perforated plate in the sloped weir.

In a further embodiment of a flotation tank to that described above, the outlet is positioned proximate the base of the wall of the final chamber.

In a further embodiment of a flotation tank to that described above, the inlet is positioned in the first chamber.

In a further embodiment of a flotation tank to that described above, each set of adjacent chambers comprises either a connector port or a fluid passage in alternating format allowing for equalization of the fluid level in adjacent chambers while preventing short circuiting of the fluid through the tank to the final chamber.

In a further embodiment of a flotation tank to that described above, the tank further comprises a manifold in fluid communication with each chamber for inputting or withdrawing fluid from the tank.

In a further embodiment of a flotation tank to that described above, the sloped weirs of the tank are aligned with one another in the adjacent chambers.

In a further embodiment of a flotation tank to that described above, the sloped weirs of the tank are offset with one another in at least two of the adjacent chambers.

In a further embodiment of a flotation tank to that described above, an upper edge of the skimming weir comprises at least one notch to promote transfer of the unwanted phase into the skim oil trough.

In a further embodiment of a flotation tank to that described above, the tank further comprises an inlet in fluid communication with each chamber for injecting a gas into the chamber, optionally in the form of micro-bubbles.

In a further embodiment of a flotation tank to that described above, the contaminant comprises hydrocarbon, emulsified oils, or heavy oils.

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In a further embodiment of a flotation tank to that described above, the fluid is produced water.

In a further embodiment of a flotation tank to that described above, the coalescing media is a fixed media.

In a further embodiment of a flotation tank to that described above, the coalescing media is a non-fixed media.

In a further embodiment of a flotation tank to that described above, the coalescing media is positioned in the interconnecting passage.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric view of one illustrative embodiment of a gas flotation tank including five chambers;

FIG. 2 is a top plan view of the gas flotation tank shown in FIG. 1;

FIG. 3 is an isometric side view of the gas flotation tank shown in FIG. 1;

FIG. 4 is a cross sectional view of the gas flotation tank shown in FIG. 1 along the dividing wall between the first and second chamber;

FIG. 5 is a cross sectional view of the gas flotation tank shown in FIG. 1 along the third chamber showing the perforated plate allowing for ingress of fluid from second chamber into the third chamber;

FIG. 6 is a cross sectional view of the gas flotation tank shown in FIG. 1 between the sloped weir and the skim oil trough showing the connecting ports between the first and second chamber and the third and fourth chamber allowing for fluid communication between these chambers and ingress of fluid from the first chamber into the second chamber and from the third chamber into the fourth chamber;

FIG. 7 is a chart of chamber residence time against cumulative removal efficiency demonstrating increased removal efficiency as the number of sequential chambers increases;

FIG. 8 is an isometric view of a further illustrative embodiment of a gas flotation tank including five chambers wherein the sloped weirs of the chambers are arranged at varying positions;

FIG. 9 is an isometric cross sectional view of the gas flotation tank shown in FIG. 8 along a divide of the first chamber;

FIG. 10 is an isometric cross sectional view of the gas flotation tank shown in FIG. 8 along the dividing wall between the first and the second chamber;

FIG. 11 is an isometric cross sectional view of the gas flotation tank shown in FIG. 8 along a divide of the second chamber;

FIG. 12 is an isometric cross sectional view of the gas flotation tank shown in FIG. 8 along a divide of the third chamber;

FIG. 13 is an isometric cross sectional view of the gas flotation tank shown in FIG. 8 along a divide of the fifth chamber; and

FIG. 14 is a schematic showing one embodiment of an interconnecting passage including an optional coalescing media.

DETAILED DESCRIPTION

Described herein are systems, apparatuses, techniques and embodiments of gas flotation tanks suitable for at least partially removing or capturing contaminants or unwanted phases from a fluid, such as produced water and methods of doing same. It will be appreciated that the methods, systems,

apparatuses, techniques and embodiments described herein are for illustrative purposes intended for those skilled in the art and are not meant to be limiting in any way. All reference to embodiments and examples throughout this disclosure should be considered a reference to an illustrative and non-limiting embodiment or an illustrative and non-limiting example.

It will be appreciated that reference to a contaminant or unwanted phase includes hydrocarbon or contaminants or phases that at least partially comprise hydrocarbon but are not limited to hydrocarbon and may include other or alternate contaminants that behave in such a manner that a gas flotation tank could be useful in their removal from a fluid.

FIGS. 1 and 3 are isometric views of an embodiment of a flotation tank, such as a gas flotation tank, for removing contaminants, such as unwanted phases, lighter than water hydrocarbon, and/or oil, crude or refined oil, or emulsions, from a fluid, such as produced water. A gas flotation tank is shown generally at 10 and is comprised of a tank floor 50 defining the bottom of the tank 10 and a pending tank wall 45 defining the periphery of the tank 10. The gas flotation tank 10 is divided into a plurality of sequential chambers for holding and imparting a generally rotational, tumbling or circular current of the produced water in each individual chamber in a generally longitudinal direction of the chamber such that the surface of the fluid moves towards a skim oil trough 15 for capturing contaminant such as hydrocarbon or oil, from the surface of the fluid skimmed off the top of the fluid.

A series of dividing walls 65 are used to define each chamber. Although the tank 10 shown throughout the figures contains five chambers, it will be appreciated that the tank may have fewer or additional chambers depending on the properties and rheology of produced water to be cleaned, the velocity of the fluid, the rate of purification, etc. Each chamber of the tank is connected to the adjacent chamber via an interconnecting passage 75 (shown in FIGS. 9, 10 and 14) that allows for transfer of the fluid from one chamber to the next.

An inlet 20, generally positioned towards an upper region of the wall 45 is used to input contaminant containing fluid, such as produced water, into the tank 10 and into the first chamber of the tank 10. A sloped weir 40 bisects each of the chambers of the tank 10 for inducing the rotational, tumbling or circular current in each individual chamber. The fluid, such as produced water, is input into the first chamber from the inlet 20 in sufficient proximity to the sloped weir 40 to induce a rotational, tumbling or circular current within the first chamber. It will be appreciated that a rotational current in the longitudinal direction of the chamber is induced by the sloped weir 40 that promotes the contaminant, such as lighter than water hydrocarbon, to rise to the surface of the water in the first chamber while the cleaner and thus heavier water is pushed downwards towards the floor 50 of the tank. A skimming weir 35 separates the chambers of the tank 10 from a skim oil trough 15 wherein contaminant, such as oil, is collected as it is skimmed over the weir from each of the chambers. In one embodiment, the skimming weir 35 comprises a one or a plurality of V-shaped notches (not shown) in the upper end of the weir 35 to allow for oil to skim over the weir and into the skim oil trough 15. In an alternative embodiment, the upper end of the skimming weir may include other shapes of notch to promote skimming of the unwanted phase into the skim oil trough 15 or may simply contain no notches on the upper end of the skimming weir. Once skimmed from the produced water, the oil may be collected using any suitable means.

To allow for more effective removal of contaminant via the skimming weir 35 into the skim oil trough 15, before the fluid is transferred to the adjacent chamber, the interconnecting passage 75 may collect fluid from substantially the base or a lower region of the sloped weir of a first chamber thereby allowing for increased flow path of the rotating fluid. The interconnecting passage 75 may then output the fluid into the adjacent chamber on a backside of the sloped weir 40 of the adjacent chamber. The input fluid into the adjacent chamber has a rotational current imparted thereon by the sloped weir and the fluid transfer onto the next adjacent chamber may be carried out in a similar manner. The interconnecting passage 75 may be formed with the slope weir 45 in combination with a baffle. Further optional features for promoting absorption or coalescing of the contaminants as they pass through the interconnecting passage 75 will be discussed in further detail below with reference to FIG. 14.

The first and the adjacent chamber, referred to as chamber two or the second chamber, may also be fluidly connected via a connecting port 60 situated in the lower region of their dividing wall 65. By positioning the connecting port 60 in the lower region of the dividing wall, cleaner water is transferred from the first chamber to the second chamber allowing for equalization of the fluid levels in these adjacent chambers. It will be appreciated that the cleaner water is water having a lower contaminant content than that input into the first chamber.

Once in the second chamber, a rotational current is again induced by a sloped weir 40 to promote the contaminant to rise to the surface of the fluid in the second chamber while the cleaner water is pushed downwards towards the floor 50 of the tank. Again, contaminant is skimmed from the second chamber into the skim oil trough 15 over the skimming weir 35 and the fluid in the second chamber is further purified relative the fluid in the first chamber.

It will be noted that there is no connecting port between the second and third chambers in order to avoid short circuiting of the fluid from the first chamber to the third chamber without a significant reduction in contaminant content. Avoiding short circuiting of the fluid through the tank increases the retention time in the tank and therefore generally allows for a greater reduction in contaminant via skimming from the top of the fluid in each chamber over the skimming weir 35 and into the skim oil trough 15.

By positioning the interconnecting passage 75 a suitable distance from the connecting port 60 the fluid must pass through sufficient rotational current to promote the rising of the contaminant to the surface before fluid is communicated from the second to the adjacent third chamber thereby providing fluid having a lower contaminant content to the adjacent third chamber while mitigating short circuiting.

To allow for equalization or substantial equalization of the fluid levels between chambers wherein there is no connecting port, a fluid passage 70 is used to allow fluid to pass through the sloped weir 40 in these chambers such as chamber 3. In this way, fluid is both transferred in the rotational current of the third chamber but can flow through fluid passage 70 in the event that difference in fluid levels between the second and third chamber is substantially different. As contaminant rises to the top of the chamber it is skimmed off the top and over the skimming weir 35 and into the skim oil trough 15 thereby reducing the contaminant content in the third chamber relative the second chamber.

It is the combination of a connecting port between the first and second chambers together with the interconnecting passage and the fluid passage that allows for both fluid

transfer from chamber to adjacent chamber while mitigating short circuiting. This setup also allows for equalization or substantial equalization of the fluid level in adjacent chambers reducing the risk of collapse of a divider wall. Once this alternating setup of connecting ports and fluid passages is established, any suitable number of chambers may be used in the flotation tank **10**.

In one embodiment, as shown throughout the figures, the fluid passage **70** may be in the form of a perforated plate.

Furthermore, it will be appreciated that the sloped weir **40** may be positioned at various points in the chambers and it is not essential that the sloped weirs **40** be arranged in a line as shown in the FIGS. **1** to **6**. For example, the sloped weirs **40** may be offset from one another as shown for example in the non-limited embodiments illustrated in FIGS. **8** to **13**. By adjusting the positioning of the sloped weirs **40** the rate of the current in each chamber may be controlled and adapted as desired or as necessary.

The sloped weirs induce a rotational current within each chamber. The rotational current allows for a lengthened flow path throughout a tank relative a typical tank of the same diameter. The lengthened flow path allows for the separation of phases have a specific gravity (SG) approaching that of water such as emulsified oils and viscous fluids such as those used in AEOR polymer flooding. In addition, the increase in flow path allows for a greater opportunity for bubbles or micro-bubbles to come into contact substantially attach with contaminants in the fluid thereby gradually floating or bringing them to the surface for eventual skimming into the oil trough **15**.

A manifold **25** in fluid communication with the chambers of the tank **10** may be used to fill or empty the tank **10** prior to operation or for maintenance of the tank **10** as needed.

The outlet **55** may be positioned in the final chamber of the tank **10** opposite the inlet chamber thereby allowing for the passage of the fluid through all of the chambers thus enabling the skimming of the contaminant in each chamber resulting in the greatest reduction of contaminant from the fluid being output from the tank.

FIGS. **2**, **3**, **4**, **5** and **6** shows various views of the tank **10** and the fluid passages **70** and alternating connecting ports **60** allowing for fluid communication between adjacent chambers while mitigating short circuiting and allowing for at least partial equalization. As can be seen from the figures, an interconnecting pipe has been omitted from the tank **10**. Such omission also allows for the omission of associated bypass lines and valves thereby reducing the complexity of the design and associated costs and maintenance. Further, scalability of the design is facilitated.

The designs described herein allow for better handling of upset conditions as the flow from chamber to chamber is less restricted through the use of the interconnecting passage **75**, connecting ports **60** as well as the fluid passage **70** and **85**, respectively, which alternate between each chamber to avoid short circuiting while helping balance the fluid levels of the chambers while promoting contaminant removal through the avoidance of short circuiting.

The avoidance of the interconnecting pipe allows for the increased ability to build tanks capable of larger flows as the design offers a larger scalability. In addition, applications that require similar flows but longer retention times are also made possible.

In addition, situating the fluid passages **70** and/or **85** in the sloped weirs to create the interconnection between various chambers as well as the interconnecting passages **75** may also act to reinforce the tank, whereas an interconnecting

pipe offers little to no structural benefit and also requires its own structural supporting incremental to what was required by the tank itself.

In addition to the benefits associated to operation of the tank **10**, the tank **10** including the alternating setup of connecting ports **60** and fluid passages **70** and **85** is less sensitive to tank filling and draining as the interconnecting ports and fluid passages allow for less restricted flow from chamber to chamber. Alternating between fluid passages and connecting ports helps balance the fluid levels in adjacent chambers during filling and draining. As the fluid levels of adjacent chambers is substantially equalized, a reduction in structural requirements is observed relative to flotation tanks based on an interconnecting pipe setup.

It will be appreciated that the connector ports **60** and the fluid passages **70** and **85** should alternate from chamber to chamber to ensure that short circuiting is reduced or prevented while still allowing for at least partial equalization of the fluid level between adjacent chambers.

Further, reduced external piping and valves is required. Typically several external pipes are used for balancing during filling and draining in a setup that includes an interconnecting pipe. These are not required with the tank disclosed herein.

By utilizing the alternating setup outlined herein, a longer flow path is established that allows for removal of contaminant from the fluid input before reaching the outlet **55** in the final chamber. In addition, a significant component of the flow path is horizontal as opposed to vertical in typical designs. This horizontal flow path allows for bubbles or micro-bubbles to attach with contaminants to promote their rise to the surface of the rotational fluid for skimming off.

FIG. **7** demonstrates the relationship that exists that shows that performance is a function of RT vs the number of sequential chambers (separators). Although the tank described herein comprised of five chambers, this suggests that additional chambers should experience an increase in performance.

It will be appreciated that in addition to the rotational current induced by the sloped weirs **40**, bubbles, optionally in the form of micro-bubbles, may be added to each chamber via an inlet (not shown) to further promote the rising of the contaminant, such as hydrocarbon, to the surface for skimming off into the skim oil trough **15**. The micro-bubbles may be added toward to base of the dividing wall, optionally in proximity to the connecting ports and act to adhere to the contaminant, such as oil, to promote the rising of the oil to the surface. A smaller bubble may be used to lower the rise velocity thereby increasing the opportunity for adherence to the contaminant. Micro-bubbles may alternatively or additionally be added at the base of the sloped weir **40**.

In addition to using the interconnecting passage **75** to allow for transfer of fluid from one chamber to an adjacent chamber, the interconnecting passage **75**, in an alternative embodiment, may be used to transfer the liquid and also to concentrate the zone of gas/liquid contact of the contaminant to the bubbles or micro-bubbles. For example, the bubbles or micro-bubbles may be introduced in the interconnecting passage **75** instead of or in addition to introducing the bubbles or micro-bubbles in the chambers themselves. Such a setup of introducing the bubbles or micro-bubbles in a narrow zone allows for an improved probability of contact and attachment with the contaminant in the fluid. The introduction of gas may be concentrated to a more confined space, such as the interconnecting passage **75**, and then released near the surface as it exits the interconnecting passage **75** where it can effectively be removed from the

fluid. Typically, other technologies work on a principle of dispersing gas in a larger volume, for example within a chamber, as opposed to concentrating the gas into a narrow zone.

FIG. 14 shows an optional embodiment of an interconnecting passage that includes a coalescing media 100 for absorbing or coalescing contaminants as they pass through the interconnecting passage 75. The media 100 is suspended above the opening of the interconnecting passage 75, as shown in FIG. 14, thereby allowing the fluid to pass through the media 100 as it moves to the adjacent chamber.

It will be appreciated that the media 100 may be positioned at any suitable position within or proximate the interconnecting passage 75 within or partially within the path of flow of the fluid so that fluid passes through the media 100. It will also be appreciated that the coalescing media 100 may be positioned in or proximate one or more or each of the interconnecting passages 75.

The media 100 may be either a non-fixed media or a fixed media. Some examples of non-fixed media includes "random packing" media, nutshells, etc. Some examples of fixed media includes a corrugated plate, fixed packing, etc.

The purpose of the media 100 is to increase the droplet or particle size of the contaminant as it passes through the interconnecting passage 75 to improve the buoyancy or floatability of the increased size of droplet or particle thereby promoting the droplet or particle to the surface for skimming.

The media 100 may be used in conjunction with the gas bubbles/microbubbles, or in place of the gas bubbles. In addition, the flow rate of the gas bubbles may be increased intermittently, as required or desired, to flush out and clean the coalescing media 100. It will be appreciated that the gas flotation tank shown in FIGS. 8 to 13 operates in a similar manner to that described above with reference to FIGS. 1 to 6 with the difference that the sloped weirs 40 are offset from one another in the sequential chambers. As will be appreciated, by manipulating both the positioning of the sloped weirs and the slope of the weirs, the velocity profiles of the fluid may be altered to obtain a more desirable separation and/or removal of the unwanted phase or contaminant.

It will be appreciated that the present design utilizes an interconnecting passage to transfer the fluid from chamber to chamber and, generally, only use the fluid passages and connecting ports to balance the chambers, whereas a serpentine tank uses perforated plates or openings to transfer fluid from one chamber to the next. Further, the present design may use the interconnecting channels, typically comprised of baffles and weir plates, to create the rotational or circular flow pattern in each individual chamber. This is used to hydraulically skim the undesired contaminants and to bring them to the surface faster and giving them more opportunity to reach the surface more often (a result of the water weir plates and the circular pattern they induce). As the length of the flow path is considered to have an impact on the separation of contaminants including phases, separation may be achieved through the rotational or circular pattern in a smaller volume as opposed to using the length of the chamber (reusing a smaller volume several times in the circular pattern instead of flowing horizontally once through that volume). The result of these can be a reduction of required retention time which in turn dictates the volume (size) of the tank. In various embodiments, the tank as disclosed requiring $\frac{1}{3}$ th to $\frac{1}{12}$ th the time (or volume) for identical scenarios. The present design allows for a single (shared) skimming means represented by the skimming weir in combination with the skim oil trough, and a single point

on the tank (nozzles, piping, and valves reduced) in which the unwanted contaminants may be removed.

It will be appreciated that the embodiments outlined herein are not intended to be limiting in any way and are merely illustrative of the invention. Modifications, alternations, substitutions and extensions of the design may be made which should be considered to be within the scope and spirit of the invention.

We claim:

1. A flotation tank for removing a contaminant from fluid input into the flotation tank, the flotation tank comprising; a floor defining a bottom of the tank and a depending wall defining the sides of the tank; a series of adjacent chambers within the tank separated from each other by dividing walls, each chamber comprising a sloped weir for inducing a rotational current within the chamber; a skim oil trough spanning each chamber and separated from each chamber by a skimming weir, the skimming weir opposite the sloped weir; an inlet in fluid communication with a chamber of the series of adjacent chambers for inputting a fluid comprising a contaminant, the inlet situated proximate the sloped weir of the series of adjacent chambers for inducing a rotational current to fluid input into the chamber; each chamber in fluid communication with the adjacent chambers via an interconnecting passage positioned substantially towards the bottom of the dividing wall of each chamber and substantially opposite the skim oil trough, the interconnecting passage allowing passage of fluid from a chamber to a backside of the sloped weir of the adjacent chamber; a connector port in the dividing wall between two adjacent chambers for providing fluid communication between the two adjacent chambers; a fluid passage in the sloped weir of at least one of the chambers of the series of adjacent chambers allowing for fluid transfer between adjacent chambers through the sloped weir of the at least one chamber; and an outlet in fluid communication with one of the chambers of the series of adjacent chambers outputting produced water;
- a coalescing media positioned in or proximate one or more of the interconnecting passages for absorbing or coalescing contaminants as they pass through the interconnecting passage; wherein the connector port and the fluid passage are situated in alternating adjacent chambers.
2. The flotation tank of claim 1, wherein the connector port is positioned in the base of the dividing wall proximate the skimming weir.
3. The flotation tank of claim 1, wherein the interconnecting passage is positioned at one end proximate the base of the sloped weir and at the other end in proximity to a backside of the sloped weir of the adjacent chamber.
4. The flotation tank of claim 1, wherein the fluid passage is positioned proximate the base of the sloped weir.
5. The gas flotation tank of claim 1, wherein the fluid passage is a perforated plate in the sloped weir.
6. The flotation tank of claim 1, wherein the outlet is positioned proximate the base of the wall of the final chamber.
7. The flotation tank of claim 1, wherein the inlet is positioned in the first chamber.
8. The flotation tank of claim 1, wherein each set of adjacent chambers comprises either a connector port or a fluid passage in alternating format allowing for equalization

of the fluid level in adjacent chambers while preventing short circuiting of the fluid through the tank to the final chamber.

9. The flotation tank of claim 6, further comprising a manifold in fluid communication with each chamber for inputting or withdrawing fluid from the tank. 5

10. The flotation tank of claim 1, wherein the sloped weirs of the tank are aligned with one another in the adjacent chambers.

11. The flotation tank of claim 1, wherein the sloped weirs of the tank are offset with one another in at least two of the adjacent chambers. 10

12. The flotation tank of claim 1, wherein an upper edge of the skimming weir comprises at least one notch to promote transfer of the unwanted phase into the skim oil trough. 15

13. The flotation tank of claim 1, further comprising an inlet in fluid communication with each chamber for injecting a gas into the chamber, optionally in the form of micro-bubbles. 20

14. The flotation tank of claim 1, wherein the contaminant comprises hydrocarbon, emulsified oils, or heavy oils.

15. The flotation tank of claim 1, wherein the fluid is produced water.

16. The flotation tank of claim 1, wherein the coalescing media is a fixed media. 25

17. The flotation tank of claim 1, wherein the coalescing media is a non-fixed media.

18. The flotation tank of claim 1, wherein the coalescing media is positioned in the interconnecting passage. 30

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